SCIENCE

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RECENT PROGRESS IN SOLAR PHYSICS AS BEARING UPON THE CAUSE OF THE ICE AGE.

AMONG the many hypotheses invoked to find an adequate cause for the glacial period, that of a time of diminution of the sun's emission of heat has had little consideration. Although apparently naming a cause adequate to the effect, it seemed too violent an assumption, and one opposed to generally accepted fact, that the supply of heat from the sun could vary to any material amount. The universal conception of the solar orb and its activities was that of extreme steadiness and uniformity of behavior, as being almost an emblem of immutable law. Any change or abatement in the sun's energy in supplying heat and light seemed as foreign to a proper notion of that body as would be a deviation from punctual rising and setting as laid down in the almanac.

Hence, in the presence of the brilliant and imposing astronomical theory of Dr. Croll, the more obvious hypothesis of solar variation lapsed out of sight. Of late, however, the former theory is becoming discredited by the growing clearness of evidence that the ice age was too recent to be accounted for thereby. The rates of recession of the Niagara gorge and of the falls of the Mississippi render it difficult to account for a continental glacier still existing seven thousand years ago, by an eccentricity of the earth's orbit which occurred fourteen times as far back in the past.

During the quarter-century since Dr. Croll's theory came into vogue, our knowledge of solar physics has been enormously developed and quite revolutionized. Possibilities and probabilities as to the variability of the sun's emission of heat are now well known, which then were not even matters of vague conjecture. Inspection of the structure and activities of the sun by means of the spectroscope has wholly changed the former conditions for reasoning about its variability.

The most conspicuous result of this spectroscopic inspection is our knowledge that the sun exhibits the most violently energetic activity all over its surface, far into its depths, and far outside of the photosphere. It continually generates and radiates into space almost inconceivable floods of light and heat. This is attended by intensely violent ebullition at the surface, in which vast streams of fluid matter are constantly flung aloft tens and hundreds of thousands of miles above the photosphere. The most titanic eruptions of earth, such as Krakatoa, are, when compared with those hourly occurring in the sun, far less than the dust-whirl of the street is to the tornado that wrecks a city.

I adduce this fact of violent ebullient activity in the sun as lending a presumption of more or less inequality in that activity. It gives the impression of contending forces arrayed against each other, necessarily disturbing equilibrium, and forbidding an equable and uniform emission of light and heat. Such inequality is markedly indicated by the known periodicity of the cyclonic sun-spots, and their attendant cosmic magnetic disturbances. There still lack results of actual observation to verify the fact of such fluctuation. The younger Angström of Sweden is understood to be now conducting delicate observations with this intent.

A vastly more extended area for observation and classification of facts relating to solar physics has been opened in the new department of stellar spectroscopy in which Dr. Norman Lockyer is the worker best known to the public. By the classification of the spectra of many hundreds of fixed stars and nebulæ, a series of grades of solar evolution have been approximately determined, beginning with suns incipiently gathering from diffused nebulous matter, and going on through successive stages of accumulation, concentration, intensifying heat, culmination, decline, and approaching extinction. All these stages are determined and classified by the peculiarities of their spectra. Dr. Lockyer is thus enabled to write approximately the history of a sun from its earliest genesis to its extinction as a luminary. Our own sun has been definitely assigned by the character of its spectrum to a class of stars of decreasing temperature, which have passed the culminating point of their activity, and are going on towards decline, like Procyon, Capella, and Arcturus. Aldebaran, Altair, and Alpha Cygni are examples of another class approaching their culmination, and increasing in brightness. Sirius is in a still earlier and more vaporous stage.

While the known violence of the sun's internal activity is suggestive of frequent transient variations in the amount of heat emitted, the above named long progressive changes are equally suggestive of vast secular oscillations in the course of the increase and decrease observed. It seems, indeed, quite impossible that those long-continued progresses of increase and subsequent decline in the heat and light of solar orbs should go on with absolute uniformity of gradation. All such processes of active change in nature are characterized by fluctuation, by alternating ebb and flow; and such a process as this would be the last to show an exception to the rule. It involves a continual balancing of mighty contending forces, forever swaying the resultant thermal condition up and down with varying divergence from an even grade of increase or decrease.

It is only in harmony with the universal laws of material activity — and it is nearly impossible to conceive it otherwise — that the heat of the sun, as it slowly diminishes through the ages, should at intervals make strong sweeps upwards or downwards, again recovering itself to its average grade of slow decline, rather than that it should progress in a uniform and imperceptible diminution. It thus seems in the highest degree probable that the sun is subject to considerable secular variations in its heat, such as might have caused the glacial period, as well as the just preceding age of arctic warmth.

As observed above, the enormous violence of the sun's internal movements, which is actually seen to exist, seems necessarily to involve fluctuation in its effects. Such opposing energies cannot uniformly so balance each other as to produce a uniform emission of light and heat. An enormous expenditure of force is going on with the progressive condensation of the vast orb. Volumes of heat and light inconceivably great are being every instant shot forth and dis-

tributed into boundless areas of space. All this is supplied by the contraction of the sun's bulk. It is in place now to specify some of the interacting and counteracting forces involved in this process of shrinkage of diameter and radiation of heat. We shall more clearly see causes of inevitable disturbance of equilibrium in the constantly varying energy of the different factors which play unequally against each other.

Every atom of the solar orb is being continually drawn towards its centre by the gravitation of the sun's own tremendous mass; but this tendency is resisted by the intense heat, which causes each particle to repel its neighbor, and so to prevent and delay that condensation to compact solidity which is to be the ultimate result. Heat must be parted with before the strenuous behest of gravity can be obeyed. Thus the process of contraction goes on with extreme slowness, only by means of, so to speak, the squeezing-out of immense volumes of heat from the whole mass. The result is an imperceptible contraction of bulk, leaving the sensible heat practically undiminished, although latent heat has been copiously expended. The heat thus continually released, and oozing from every molecule throughout the bulk of the mighty orb, finds escape from the interior to the surface by means of vast upboiling currents of superheated fluid which carry out the heat; in other words, by the process of convection.

Now observe the elements of variation as found in the interacting forces involved. The primary factor in this combination is the force of gravitation; but gravitation must increase inversely as the square of the sun's radius. As the bulk shrinks, gravity multiplies. When the sun had twice its present diameter, its particles drew together only one-fourth as hard as they do now. Here, then, is a steadily changing factor tending to disturb the uniformity of the heat emitted.

A second ever-changing factor is the area of the radiating surface of the photosphere. This varies, not inversely like gravitation, but directly as the square of the sun's radius. When the sun was twice its present diameter, the area of its photosphere was four times as extensive: in other words, the heat had four times as wide a gate to find escape through. This, again, tends to disturb uniformity in the emission of heat.

A third element of variation is to be found in molecular repulsion, which varies not only with the amount of sensible heat, which is possibly still rising as the sun grows denser, but it will also vary as the square of the decreasing distances between the crowding molecules. This influence is opposed to that of gravitation, and tends to prevent condensation. This varying quantity constitutes a third antagonist in the fray, as the war sways to and fro in the sun's interior.

A fourth factor is the slowly lessening distance from the sun's centre to its surface, which facilitates the transit of the outgoing currents conveying to the surface the superheated fluids of the contracting interior. As the sun shrinks, the path to the surface shortens directly as the radius, thus tending to increase the escape of heat.

But counteracting this is the increasing density of the sun's contents, which varies inversely as the cube of the radius; that is, as the shrinkage of bulk. The mass of the sun is now eight times as dense as when of twice its present diameter. This greatly increases the resistance to movement of internal currents, just as one hundred people in a hall of a given size will move about more than twice as easily as two hundred people in the same hall who crowd and jostle each other.

A sixth and perhaps very variable factor which powerfully retards the radiation of light and heat, is the enveloping atmosphere of the sun, estimated at several thousand miles in depth, and of considerable density. This atmosphere, like an enswathing blanket, arrests a large portion of the radiated heat. Now, the quantity of this atmosphere being assumed as constant, its depth will tend to vary inversely as the area, that is, as the square of the sun's diameter, and so the radiation of heat be hindered increasingly as the sun shrinks.

It is quite impossible, however, that the quantity of atmosphere outside of the photosphere should remain exactly constant. Large quantities are evidently carried down into the sun's interior by the plunging rush of the sun-spot vortices, no doubt to boil up again to the surface.

Added to the regular atmosphere are the red cumulus protuberances above the atmosphere, composed of more tenuous vapor forced out perhaps by electric repulsion. These must contribute to arrest the escape of heat, and are also variable in quantity.

This brings us to another probable element of a perturbing nature in its influence upon the escape of heat; that is, electrical repulsion. It is probably this which not only drives forth the red protuberances to such an enormous height, but which also shoots out the broad streamers of the sun's corona. The tails of comets are probably forced outwards by a similar repulsion from the sun.

As this force is habitually attendant upon molecular activity and the generation of heat, it must be subject to considerable fluctuation with the violent internal agitation of the orb. To all this fluctuation the earth's magnetism constantly responds, like a delicate galvanometer. How much more powerfully, then, must the sun's own atmosphere respond, dilating and bristling out with every rising wave of electrical agitation! Such dilatation of the atmosphere and its vast appendages cannot fail to diminish the radiation of heat, like a bird roughing its feathers in the cold.

Miss Agnes Clerke describes those stars in the same class as our sun as being more strongly electrified than the others, and hence likely to be more active in their fluctuations of repelling force.

Recent developments in chemical science promote belief in the existence of elementary forms of matter not yet actually observed. Certain peculiarities in the spectrum of the sun are thought to indicate that much of its matter is still in such elementary forms, owing to its intense heat. This increases the probability that great chemical processes are going on in the sun, which are attended with evolution of heat, and which thus contribute to the complexity of causes producing variation thereof.

Should we adopt the conjecture of Mr. Proctor and others, that the supply of heat in the sun is largely maintained by a bombardment of meteorites supposed to be densely swarming about it, we might find in this another element of variation. This is, however, hardly more than unsupported conjecture.

The foregoing enumeration of certain and probable factors in the sun's internal activity, as contributing to produce much variation in the resultant emission of heat and light, is necessarily but rude and imperfect; yet at least it serves to illustrate and lend probability to the hypothesis advocated in this essay. Some of the causes of fluctuation named seem most adapted to produce comparatively brief and transient inequalities of radiation, such as might easily be verified by long-extended instrumental measurements in elevated posi-

tions. It seems not unlikely that the greater part of the meteorological perturbations of our globe will be found closely connected with such transient inequalities in the sun's activity.

Some of the factors concerned seem, however, more adapted to produce secular oscillations in the sun's evolution of heat, extending through periods like the thousands of years probably occupied by the glacial age, and by the antecedent age of arctic warmth.

The one impossible thing would seem to be that the conflict of all those struggling and discordant forces should generate such an equalized and perfected balance in their resultant, that the sun's emission of light and heat should continue uniform and undisturbed from age to age; that it should not, indeed, from time to time be subject to very great fluctuations. In this view of the question, it seems not unreasonable to claim at least a place of high consideration for this hypothesis among other unverified hypotheses of the cause of the glacial period.

It may be claimed in favor of this hypothesis that it serves to account for the antecedent age of arctic warmth, as well as for the glacial age. Dr. Croll's hypothesis wholly failed in this respect. Nor, as it occurred not earlier than the pliocene, can it be attributed to conditions belonging to the carboniferous period.

As an objection to the solar hypothesis, it has been alleged that a diminution of solar heat would forbid the evaporation required to supply a precipitation of snow adequate to form glaciers. To this it may be replied that existing glaciers, like that of Greenland, are by no means supplied from the copious evaporation of the tropics, which is all precipitated in the neighboring latitudes. They are fed from the far lesser evaporation of the neighboring open seas, including the extremities of the Gulf and Kurasiwo currents. It is estimated that a general reduction of temperature of 18° to 20° F. over the earth's surface would produce the glacial period. Even with such a reduction in the sun's supply of heat, a large evaporation would continue, as well as air and ocean currents distributing the reduced warmth. The necessarily resulting changes would not involve a suspension of evaporation and precipitation, but rather a transfer of the areas of glaciation from the arctic to the temperate zone, such as actually took place in the glacial age.

SERENO E. BISHOP.

THE CULTIVATION OF THE SUGAR-BEET IN OHIO.

"FARMERS' BULLETIN No. 3" of the United States Department of Agriculture is an abridgment of a monograph on the sugar-beet, recently compiled by Professor H. W. Wiley, chemist of the department.

Judging from European experience, it seems probable that the culture of the sugar-beet in America will be most successful within the limits of a belt of about one hundred miles on each side of the summer isotherm of 70°; that is, a line marking an average temperature of 70° for the months of June, July, and August. In Ohio this line follows approximately the southern shore of Lake Erie, so that the northern third of the State is included within the belt named.

The summer temperature is not the only climatic question that must be considered, however; as, for instance, the mild winters of southern California permit the piling of the beets in immense heaps, requiring no protection, or, at most, but a slight covering of straw, and thus extending the working season throughout the winter; whereas in northern Ohio the beets would have to be pitted or housed in expensive cellars or silos. Again, the California winter gives a season of three or four months during which planting may be done, or three times as long as in northern Ohio.

The soil most favorable to the culture of sugar-beets is one that is easily worked, and is fertile enough to produce rapid growth. The moderately sandy soils, and especially the black sands of northern Ohio, will probably be found well adapted to beet-culture. The fertile bottom-lands of the farm occupied by the experiment station at Columbus produce large crops of beets. Stiff, heavy clays will not be found satisfactory, as a rule, unless thoroughly underdrained and brought up to a high state of fertility by previous manuring and the growth of clover.

The variety of beet is an important point, but a yet more important one is the care with which the seed has been selected. In France and Germany the percentage of sugar in the beet has been very greatly increased by improvements in the production of seed.

The manufacture of sugar from beets involves the use of very expensive apparatus, and requires great technical skill. In 113 German factories the mean capital invested in each factory is nearly two hundred thousand dollars; and the total expense of manufacture is nearly eight dollars per ton, counting the beets at a little less than five dollars per long ton. The experience of the Ohio Experiment Station is, that, on suitable soils, beets can be raised at this price with a very wide margin for profit.

The bulletin referred to contains illustrations of machinery used in beet-culture, and many other interesting items which cannot be condensed into a brief abstract. The station has received a few copies of this bulletin for distribution in Ohio, and will take pleasure in sending them free of all costs to all applicants, while the supply lasts. Address Experiment Station, Columbus, O.

NOTES AND NEWS.

AN exhibition of all the means of advertising will be held at the Palais des Beaux-Arts, Champ-de-Mars, Paris, from May 17 to Sept. 15.

— For a year past, the crater of Halemaumau, in the volcano of Kilauea, Hawaii, has been in a state of high activity, the lava frequently pouring out through ducts upon the main floor of Kilauea. On March 5 sinking began, attended with slight earthquakes, extending into the neighboring district of Kau. By the 8th the collapse was complete. The interior cone, with the adjacent fire-lakes, had sunk out of sight; and the entire area of Halemaumau, over half a mile in diameter, is now occupied by a pit estimated at five hundred feet in depth. It was just five years after the last and similar collapse. As then, no fire is now in sight. Some fissure has opened in the side of the main column of lava, and discharged the contents under ground. It is perhaps not a mere coincidence that on March 4 the mercury in Honolulu reached the lowest point on record, 48°. The extreme cold of March 10 in England will be noted in this connection. A full report of the condition of Kilauea is expected from Professor Brigham, who is now on the ground.

— The forthcoming May number of the *Review of Reviews* contains, under the title "Three Empire Builders," some timely character sketches. One deals with Sir Henry Parkes, prime minister of New South Wales, the father of Australian federation, and chairman of the great constitutional convention which has just concluded its labors at Melbourne. Another deals with Sir John Macdonald. The third sketch has the Hon. Cecil Rhodes for its subject, Mr. Rhodes being the gifted young Englishman who, a few years ago, went out as a consumptive student from Oxford to regain his health in Africa, and who has been conquering a new empire for Great Britain with Capetown as its capital. Among the special features of the May number will be found an article entitled "Workingmen's Clubs vs. The Bar-Room." "The Progress of the World," an editorial department of the *Review of Reviews*, contains in the May number a map of Australia showing the newly federated provinces, several maps showing the course of the new Nicaragua Canal, and various portraits.

— At a meeting of the trustees of the Johns Hopkins University, held April 6, 1891, the president of the university stated that a lady in New England had authorized him to offer the university the sum of five hundred dollars, to be bestowed in annual prizes during the next ten years, under the following conditions: the